

## MSE 8803 G: Kinetics of Phase Transformations

Spring, 2006, T, Th 12:05-1:25 PM., Room 299, Love Building

### INSTRUCTORS:

Dr. Tom Sanders

Office: Love Building, Room 268

Dr. N. Thadhani

Office: Love Building, Room 166

**OFFICE HOURS:** By appointment. Instructor encourages use of e-mail.

E-mail: [tom.sanders@mse.gatech.edu](mailto:tom.sanders@mse.gatech.edu)

E-mail: [naresh.thadhani@mse.gatech.edu](mailto:naresh.thadhani@mse.gatech.edu)

**LECTURES:** The lectures will follow the material presented in the text and will be supplemented with additional concepts and readings from the literature for clarification. Please retain and follow the attached outline. You should read all material prior to class.

**HOMEWORK:** Homework will be regularly assigned and collected. Depending on class size, we would like you to work in groups and complete one assignment per group. Solutions to the homework problems will be covered in class. Problems on the examinations will be similar to the problems assigned for homework. A complete set of homework for each one in class will be collected at the end of the semester and graded.

**EXAMINATIONS:** There will be 2 in-class, closed book and notes examinations during the semester and the 3<sup>rd</sup> exam during the final examination period covering the last segment of the course. If a student has a legitimate conflict, prior to the examination day they must reschedule the exam.

### FALL 2005 EXAM Schedule:

Exam 1: Thursday, February 16

Exam 2: Thursday, March 30

Exam 3: Friday, May 5 (during final exam period- period 13, 8:00-10:50)

**GRADE:** Your final grade will be computed based upon your performance on the three in-class exams, final exam and the homework scaled according to the scheme below.

Examination 1                    -25%

Examination 2                    -25%

Examination 3                    -25%

Homework                         -25%

Examination 3 will be given during the final exam period.

**CATALOG DATA for MSE 8803G:**

Credits 3 (3-0-3).

Prerequisites: Graduate standing and graduate course in thermodynamics.

Description: Basic principles describing the evolution of microstructure of engineering materials with time and temperature occurring during either processing or while in-service. One emphasis of the course will be to identify the driving forces and define the pathways by which the microstructure is evolving. A secondary thread that will run through the course will be to identify the influence of the scale of the microstructure on the overall transformation kinetics. Topics will include diffusion, nucleation theory, spinodal decomposition, growth and dissolution, coarsening, sintering and morphological changes. Diffusional and non-diffusional phase changes will be studied.

References:

*Phase Transformations in Metals and Alloys*, D. A. Potter and K. E. Easterling, Chapman and Hall, 1981.

*Stability of Microstructure in Metallic Systems*, J. W. Martin, R. D. Doherty, and B. Cantor, 2<sup>nd</sup> edition, Cambridge University Press, 1997.

*Lectures on the Theory of Phase Transformations*, 2<sup>nd</sup> edition, Edited by Hubert I. Aaronson,

Chapter 1, Applications of Gibbs Energy-Composition Diagrams, by Mats Hillert, pp. 1-33.

Chapter 4, The Kinetics of Solid to Solid Nucleation Theory and Comparisons with Experimental Observations, H. I. Aaronson and J. K. Lee, pp. 165-225.

Chapter 3, Theory of Capillarity, Rohit K. Trivedi, pp.135-164.

*The Theory of Transformations in Metals and Alloys*, J. W. Christian, Pergamon Press, Oxford, 1965.

Selected references from the literature will be included.

**GOALS:**

Apply the fundamentals of thermodynamics and mathematics to the kinetics of diffusional and non-diffusional phase transformation in engineering materials.

### **PREREQUISITES BY TOPIC:**

1. Application of fundamental laws and theories of thermodynamics to materials systems.
2. Application of solution thermodynamics to the Gibbs free energy of a system.
3. Phase equilibrium and phase diagrams and the calculations of these diagrams from Gibbs free energy curves.

### **CORE TOPICS:**

#### **DIFFUSIONAL PHASE TRANSFORMATIONS**

1. The general problem of microstructural stability
  - Homogeneous and heterogeneous phase transformations
  - Driving forces for microstructural change, application of Gibbs molar diagrams
  - Mechanisms of microstructural change- the rate controlling step
  - Empirical kinetic equations, the Johnson-Mehl-Avrami Equation
2. Highly metastable alloys
  - Rapid solidification
  - Cooling rate and undercooling
  - Metastable diagrams
  - $T_0$  lines- allotropic phase boundaries
  - Massive transformations
  - Submerged phases and transformations
  - Glass transition temperature
  - Metastable and quasicrystalline phases
  - Amorphous alloys
  - Crystallization
3. Structural instability due to chemical free energy
  - Instability due to nonuniform solute distributions
  - Diffusion process as related to the Gibbs free energy of the system
  - Diffusion equations
  - Atomic theory of diffusion
  - Diffusion in concentration gradients
  - Diffusion along crystal imperfections
  - Diffusion in noncrystalline materials
  - Coring during solidification
  - Steady-state solidification, the concept of constitutional supercooling
  - Spinodal decomposition
  - Homogeneous nucleation
  - Heterogeneous nucleation
  - Growth and dissolution
4. Instability due to strain
  - Stored energy of cold work
  - Recovery

- Recrystallization
- 5. Microstructure instability due to interfaces
  - Surface energy and surface tension
  - Anisotropy of surface energy
  - Ostwald ripening
  - Sintering
  - Grain boundary reactions
  - Phase morphology

#### DISPLACIVE/DIFFUSIONLESS TRANSFORMATIONS

1. Classification of displacive transformations (shuffle/lattice-distortive)
  2. Characteristics of Martensitic Transformations (definition and terminology, lenticular/lath/acicular morphology or martensite)
  3. Theory of Martensite phase formation (Crystallography and Bain Distortion)
  4. Thermodynamics of martensite – transformation temperatures
  5. Martensite Nucleation and Growth mechanisms
  6. Athermal and Isothermal Kinetics of martensitic transformation
  7. Grain size effect on Martensite Kinetics
  8. Mechanically-induced martensite formation (stress and strain effects)
  9. Thermoelastic and Pseudoelastic Effects of Martensitic Transformation
- Magnetic Field effect on kinetics of Martensitic Transformation